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# Repetition priming and recognition of dynamic and static chimeras

Leslie L Steede, Graham J Hole

School of Life Sciences, Department of Psychology, Pevensey Building, University of Sussex, Falmer BN1 9QH, UK; e-mail: lls21@sussex.ac.uk

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**Abstract.** Chimeric faces, produced by combining the top half of a familiar face with the bottom half of a different familiar face, are difficult to recognise explicitly. However, given that they contain potentially useful configurational and featural information for face recognition, they might nevertheless produce some activation of representations of their constituent faces. Repetition priming with dynamic and static facial chimeras was used to test this possibility. Whereas half-faces produced significant repetition priming of their familiar counterparts, both types of chimera did not. When analyses were restricted to faces that were recognised during the prime phase, repetition priming was both significant, and equivalent, for chimeras and half-faces. The results suggest that the constituents of a facial chimera must be parsed, and recognised, in order for them to cause repetition priming for their familiar counterparts. Facial motion does not help with the parsing of a facial chimera.

## 1 Introduction

Models of face processing (Bruce and Young 1986; Burton et al 1990, 1991; Stevenage and Lewis 2002) that were developed from frameworks used to describe visual word recognition (Morton 1969) have greatly aided our understanding of how the human face-recognition system stores and retrieves information that is important for recognising familiar faces. The most recent model to explain the processes involved in familiar-face recognition is the interactive activation and competition (IAC) computer implementation proposed by Burton et al (1990) (figure 1).

This model proposes a number of hypothetical units that are involved in face processing. Face-recognition units (FRUs) are believed to store visual descriptions of known faces. Personal-identity nodes (PINs) allow access to semantic information about familiar faces. Semantic-information units (SIUs) store semantic information about familiar faces (eg whether the person is a film star or a politician). Excitatory links connect units that are associated with the same or related faces, and inhibitory links connect units associated with different or unrelated faces.

When the face-recognition system is presented with a familiar face, a FRU corresponding to that face becomes activated. If the level of activation passes a threshold, activation flows from the FRU to the PIN, causing the PIN associated with the familiar face to become active. When the PIN reaches a threshold, the face is recognised as familiar. PIN activation then flows to the SIU link, which allows access to semantic information about familiar faces.

The IAC model has been successful in describing various phenomena found in the face-recognition literature (Burton et al 1990). Of particular relevance to this study is that the functional mechanisms are capable of explaining repetition or identity priming. Repetition priming is the facilitation found in recognising a familiar face as a result of it being encountered previously (Bruce and Valentine 1985). Repetition priming is believed to occur because the initial presentation of a familiar face leads to activation of the link between the FRU and PIN for that individual. If the same face is presented later, activation flows more quickly via the activated link between the FRU and PIN. This facilitates a familiarity decision, compared to if that face had not been encountered by the face-recognition system for some time.

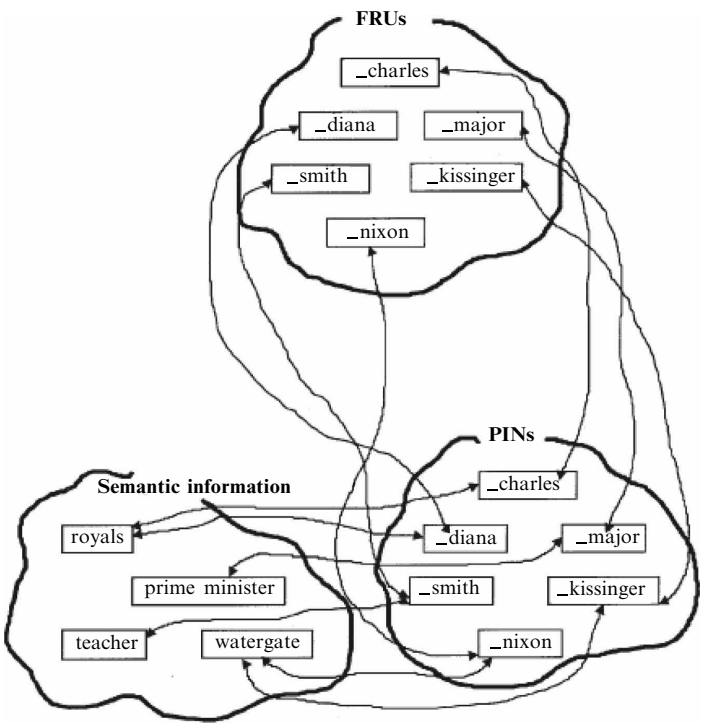


**Figure 1.** An illustration of the interactive activation and competition model (Burton et al 1990).

IAC models (Burton et al 1990; Stevenage and Lewis 2002) have been very useful in explaining the function of, and the relationship between, centrally located units (FRUs, PINs, and SIUs) believed to be operating in the face-recognition system. However, very little attention has been given to describing units that must operate at the front end of the model [eg units that feed into FRUs—labelled feature units (or FTUs) in Stevenage and Lewis's (2002) model] in order for the face-recognition system to function successfully. Specifically, very little has been said about the type of facial information that is stored at the level of FTUs, and that is sufficient to cause adequate activation of FRUs (Bruce et al 1994). IAC models (Burton et al 1990; Stevenage and Lewis 2002) suggest that FRUs might be fed by descriptions of features of familiar faces (ie hair, eyes, nose, and mouth) and their configurational properties (the distances between the features). This is supported by research that demonstrates that face recognition can occur on the basis of either configurational or featural facial information (Collishaw and Hole 2000; Tanaka and Farah 1993).

Both featural and configurational facial information have been shown to be equally useful for familiar-face recognition (Collishaw and Hole 2000). Specifically, Collishaw and Hole (2000) evaluated recognition rates when familiar and unfamiliar faces were presented in formats which forced participants to rely more on configurational or featural facial information for face recognition. Blurring was used to remove high-spatial-frequency facial information (featural detail) from familiar and unfamiliar faces, forcing participants to rely more on configurational facial information. To isolate featural facial information, familiar and unfamiliar face images were sectioned into five horizontal parts and the parts were scrambled with respect to one another. This manipulation ensured that information about featural detail remained intact (featural information), whilst information about the relationship between facial features was distorted. Whilst these two manipulations led to poorer face recognition compared to

when unaltered images were presented, recognition accuracy was equivalent for scrambled and blurred faces.

Various sources of evidence indicate that featural and configurational information are processed by different mechanisms operating in the face-recognition system. Specifically, right hemispheric dominance has been shown for faces that retain configurational information (eg upright faces—Rhodes et al 1993) and for face-recognition tasks that require holistic face processing (Rossion et al 2000). A left hemispheric advantage has been reported when the face-recognition task requires a feature-by-feature matching strategy (Bourne and Hole 2006; Hillger and Koenig 1991; Rossion et al 2000). In addition, featural and configurational facial information are affected differentially by inversion. Whilst featural information is perceived equally well when faces are presented upright or inverted, inversion severely impairs the perception of configurational information (Collishaw and Hole 2000; Rhodes 1985; Searcy and Bartlett 1996).

Studies have also provided insights into the way in which the face-recognition system analyses a face when both types of facial information are available. Young et al (1987) created chimeric faces by aligning the top and bottom halves of two different familiar faces. Participants were asked to identify either the top or the bottom halves of these chimeras. Identification was slower with upright chimeras than with inverted chimeras, or chimeras in which the two halves were misaligned. The authors suggested that this effect occurs because upright faces evoke some form of configurational or holistic processing.

In this study, we attempted to provide further insights into how the face-recognition system processes featural and configurational information, by examining the extent to which familiar chimeric faces activate representations of their constituent faces. Specifically, we were interested in the extent to which the presentation of a familiar chimera [eg the top half of Arnold Schwarzenegger (hairline, eyes, and top of nose) attached to the bottom half of Ben Stiller (bottom of nose, mouth, and chin)] causes repetition priming of its intact upper face donor (eg an intact image of Arnold Schwarzenegger's face).[1] We also compared repetition priming produced by familiar facial chimeras to that produced by facial stimuli that were limited to the top halves of familiar faces, to index any difference in repetition priming caused by altering the configurational properties of a familiar face.

It is an open question whether a familiar-face chimera might serve as sufficient input to activate representations of its constituent faces. On the one hand, research has demonstrated that facial identity can be accessed by either individual facial features or their configuration (Collishaw and Hole 2000; Tanaka and Farah 1993). Given that familiar-face chimeras contain relevant information about the facial features of their donor faces, and their configuration (ie information is available about the eyes and their distance apart, the shape of the forehead and much of the hair), it might be expected that this information might serve as sufficient input to activate FRUs.

On the other hand, there are also reasons why we might not expect a familiar-face chimera to serve as sufficient input to active a FRU. Placing half of one familiar face on top of another might result in a novel facial configuration that constrains the way in which the features are analysed, such that no activation occurs for either constituent of the chimera. In addition, if the face-recognition system computed a facial feature analysis, and relevant features were detected, it might be the case that a FRU could receive positive activation from the features that match stored facial information, and

[1] Research has shown that features in the upper portion of a face (eyes and eyebrows) are more important for face recognition than features in the lower portion of a face (nose and mouth) (Davies et al 1977; Haig 1986; Maruyama et al 1988). Consequently we restricted our analysis to evaluating recognition and repetition priming rates for the identity of the upper portion of a chimera, to provide the most stringent assessment of whether chimeric faces can prime their donors.

inhibition from the features that do not match stored facial information. An analysis like this could lead to null activation in the face-recognition system.

Furthermore, chimeric faces might be very difficult to recognise explicitly when participants are not given prompts to attend to their top or bottom halves. This may, or may not, render them as insufficient input to activate FRUs. The activation caused by unrecognised chimeras might be enough to partially activate the donor face FRU, even if there is no evidence of explicit recognition.

Activation of the face-recognition system in the absence of explicit recognition has been shown in brain-damaged individuals (Young 1994). Differential responding to familiar and unfamiliar faces has been shown through physiological responses [eg, skin conductance (Bauer 1984)], visual evoked potentials (Renault et al 1989), and various behavioural measures, including priming, and familiar, compared to unfamiliar, face matching (de Haan et al 1987a, 1987b, 1992; Young et al 1988).

Consistent with studies conducted by Brunas-Wagstaff et al (1992) and replicated by Johnston et al (1996), it may also be the case that chimeras that are not explicitly recognised, may not sufficiently activate representations of their constituent faces enough to enable repetition priming. Using different stimuli [internal and external features (Brunas-Wagstaff et al 1992) and scrambled and intact faces (Johnston et al 1996)] these researchers demonstrated that repetition priming occurred only for familiar faces which participants could explicitly and spontaneously recognise during the prime phase of an experiment. If the experimenter was obliged to provide semantic or name prompts to recognition before the participant could recognise a face, then that face did not act as a prime for itself on subsequent presentations.

We addressed both of these possibilities here by evaluating separately the amount of priming produced by chimeras that were, and were not, explicitly recognised during the prime phase. In this way, we aimed to provide insights into whether explicit recognition is necessary for significant repetition priming of familiar-face chimeras.

One variable that may influence how chimeric faces are analysed by the face-recognition system is facial movement. Many studies have shown that rigid and non-rigid facial movements can be useful for recognising facial identity (see Roark et al 2003 for a review). During rigid motion, a face changes its position and orientation with respect to the viewer, as a result of shaking or nodding the head. During non-rigid motion, the internal features of a face move as a result of expressing or talking.

Researchers have put forward two hypotheses that attempt to explain how facial motion might aid face processing (O'Toole et al 2002; Roark et al 2003). The supplemental information hypothesis (SIH) proposes that idiosyncratic facial movements, termed dynamic facial signatures, that are generated by a particular person, may be stored in memory and may facilitate familiar-face recognition (Lander and Bruce 2000; Lander et al 1999, 2001; Lander and Chuang 2005; Roark et al 2003). Direct support for the SIH comes from studies which indicate that participants are able to discriminate between different identities on the basis of their idiosyncratic facial movements alone (Hill and Johnston 2001; Knappmeyer et al 2003). In one study, Hill and Johnston (2001) used 3-D animation software to project facial movements from live actors onto a model of an average face. Participants were able to discriminate between different dynamic identities on the basis of their idiosyncratic facial movements.

Further support for the SIH comes from studies which have shown that facial motion can facilitate familiar-face recognition when static facial cues to recognition are degraded by negation (Knight and Johnston 1997; Lander et al 2001), pixellation (Lander et al 2001), and black-and-white thresholding (Lander et al 1999). The recognition advantage found in these studies is reduced when the precise dynamic characteristic of the observed pattern of motion is disrupted by presenting the frames in a jumbled order or in slow or speeded motion (Lander and Bruce 2000). In addition, the recognition advantage

appears only to be present for degraded familiar faces that are rated as having 'distinctive', rather than typical, facial movement patterns (Lander and Chuang 2005). Distinctive facial movements are more likely to be idiosyncratic than typical facial movements. Taken together, these findings have led researchers to believe that the recognition advantage for recognising degraded dynamic familiar faces appears to be due to the presence of a dynamic facial signature (Lander and Bruce 2004; Lander and Chuang 2005).

Research further indicates that non-rigid facial motion may activate representations (or FRUs) of familiar faces (Lander and Bruce 2004) more readily than static face images. In a series of repetition priming studies, Lander and Bruce (2004) found that naturally moving non-rigid faces prime static famous faces more effectively than static face primes. This priming advantage was reduced when the motion parameters were disrupted by presenting frames from the dynamic faces in slow motion. This finding lends further support to the SIH, and indicates that the priming advantage found with dynamic relative to static faces may depend on the presence of motion parameters that are characteristic of familiar faces.

The representational enhancement hypothesis (REH) proposes that facial motion might contribute to face recognition by facilitating the perception of the static structure of a face (Knight and Johnston 1997; Roark et al 2003). According to this view, when a face is viewed in motion, observers are able to extract a better structural description of the global shape of the head and the facial features relative to when a face is shown statically.

Very few studies have provided support for the REH (Pike et al 1997; Schiff et al 1986; Thornton and Kourtzi 2002). Perhaps the strongest evidence in support of the REH comes from a series of studies by Pike et al (1997), which showed that face learning was more accurate when faces were learned in a rigid motion sequence than when they were learned as a series of static images that showed the major viewpoints depicted in the rigid sequence. This finding indicates that a rigidly moving face may provide a better structural description of a face than when the major viewpoints are presented statically. Later attempts to replicate an encoding advantage by using rigid motion were unsuccessful (Christie and Bruce 1998; Lander and Bruce 2003).

Further support for the REH comes from a sequential face-matching experiment by Thornton and Kourtzi (2002). Thornton and Kourtzi showed that participants were significantly faster at deciding whether two faces had the same identity when an unfamiliar static face was preceded by a dynamic face prime than when it was preceded by a static face prime. The matching advantage found here could not result from the presence of idiosyncratic facial movements, because the participants were unfamiliar with the movements of each face. Thus, the result lends supports to the REH, as the motion benefit found is likely to reflect a 'representational advantage' afforded by dynamic face primes, relative to static face primes (Thornton and Kourtzi 2002, page 128).

It is possible that non-rigid facial motion might influence recognition and repetition priming of the constituents of a facial chimera, by providing an enhanced representation of either the configurational and/or featural information present in a chimera (Thornton and Kourtzi 2002). Here we addressed this issue by using 3-D animation software to artificially animate chimeric faces with a non-rigid facial motion pattern (expressing and talking). Artificially animating a familiar face ensures that any motion benefit found does not occur as a result of the SIH, because the motion parameters projected onto the familiar faces were not produced by either constituent of the chimera.

If non-rigid motion causes a facial chimera to be processed more configurally, we might expect a decrease in recognition and repetition priming. This is because configural processing is believed to be responsible for the difficulties in recognising the identities of a facial chimera (Young et al 1987). On the other hand, if facial motion enhances the quality of the featural information available in a chimera, we might

expect that a chimera might be processed less holistically, and that the features of either constituent of the chimera might be processed more efficiently. This might lead to higher recognition rates, and an increase in repetition priming compared to when chimeras are presented statically. Last, if facial motion increases the quality of both featural and configurational information, or does not influence configural or featural processing of facial chimeras, we would expect no differences between recognition and repetition priming for dynamic and static chimeras.

In short, evaluating how the face-recognition system is activated by recognised and unrecognised, dynamic and static chimeras may throw some light onto what constitutes effective input to activate a FRU, and, more specifically, may give insights into how the face-processing system uses information about facial features and their configuration to compute identity.

## 2 Method

### 2.1 *Participants*

Sixty participants, naive to the purpose of the experiment, were recruited from the University of Sussex paid research-participation pool. Participants were paid £5 upon completion of the experiment. Eleven participants were male.

### 2.2 *Design*

A between-subjects design was used in which participants were randomly assigned to one of four experimental conditions which differed in terms of the type of facial stimuli that were viewed during the prime phase. There was a dynamic chimeric prime condition, a static chimeric prime condition, a dynamic half-face prime condition, and a static half-face prime condition. Fifteen participants participated in each of the four conditions.

### 2.3 *Materials*

20 chimeras were constructed by obtaining 40 photographs of famous faces shown from a frontal viewpoint from the www.google.co.uk image database (see appendix). These included well-known male actors and political leaders. The chimeras were constructed with Adobe Photoshop software. Each face (from the neck up) was 'cut and pasted' onto a white background, and then sectioned horizontally approximately across the middle of the nose. One half of each face was discarded. The remaining halves were used to construct the chimeric faces. Where necessary, halves were altered slightly in size to produce a better join between the two halves. Using Adobe Photoshop we changed all face halves from colour to greyscale. Gross differences between the faces in contrast, and overall luminance, were reduced by using the brightness and contrast controls within Photoshop. The blur and smudge controls were used to remove the line that separated each facial half. This ensured that each chimera resembled a novel face, rather than a face constructed from two constituents.

Images of chimeras were then imported into facial animation software, 3dMeNow Professional, and a 3-D model was constructed of each chimeric face.[(2)] Animation controls within 3dMeNow were used to create a non-rigid motion sequence that was then transposed onto each of the familiar chimeras. The motion pattern showed each face

[(2)] In 3dMeNow, the developer uploads images of a face (front and/or profile views) and application tools are used to place markers around the main features of each facial image (outer contour of the head, hairline, eyes, nose, and mouth). Upon placing these markers, the software computes the structure of the head and produces a 3-D model of the face. Research has shown that the recognition of different viewpoints of face models constructed in this way is comparable to recognition rates obtained from natural facial images. Across 11 studies, mean accuracy was, on average, 7% less for recognising images created with 3dMeNow compared to natural facial images (see Bailenson et al 2004). However, this reduction could be largely explained by differences between the hairline and hair of natural photographs compared to 3-D models of faces. When the hair was occluded, mean reduction in accuracy favouring natural face images was only 4%.

speaking letters and expressing (eye-brow movements to emulate a surprise expression and blinking). Small rigid movements, mainly in the form of head nodding, were also incorporated into this animation. The non-rigid motion sequence lasted 2 s.

The motion parameters were designed to be similar to the facial movements that were used by Lander and Chuang (2005) in an experiment which showed that participants were more accurate at recognising the identity of familiar faces (lecturers and staff members in the psychology department at the University of Manchester) when the faces were degraded and presented moving, compared to when they were presented static. The faces were animated so that the movements appeared as natural as possible. The dynamic chimeras were created by rendering the non-rigid motion pattern onto each familiar chimeric face model with the PAL full screen option ($720 \times 576$) as display resolution, a frame rate of 30 frames $s^{-1}$, MS MPEG – 4 3688 V3 as the compression type, and the local playback (2 Mbits) option, as the display rate.

Static chimeras were constructed by importing the dynamic chimeras into video editing software, Fade to Black. The first frame of each moving chimera, that showed the face with a surprise expression, was altered with the aid of edit features such that it was displayed for 2 s. The static clip was then rendered by using the same output parameters as the dynamic chimeras. Dynamic and static half-faces were constructed directly from the dynamic and static chimeras by cropping the bottom halves of the chimeras to the middle of the nose. They were then rendered by using the same output parameters as the dynamic and static chimeras. Dynamic and static prime stimuli measured approximately 5.23 cm $\times$ 4.80 cm. Participants viewed prime stimuli at 60 cm (faces thus subtended 4.98 deg $\times$ 4.57 deg).[3]

Intact famous images (20) and intact non-famous images (20) were used for the test phase. Intact famous images shared the identity of the top halves of the chimeras shown during the prime phase. These images showed each familiar face from a frontal viewpoint with a neutral expression. The use of faces with different expressions during the prime and test phase minimises the chances that any priming effects found in this experiment were due to priming of accidental details in the facial pictures, rather than person identity priming (Bruce and Young 1998).

The 20 intact non-famous faces were obtained from the Psychological Image Collection at Stirling University (http://pics.psych.stir.ac.uk/cgi-bin/PICS/New/pics.cgi). These images showed non-famous faces with a neutral expression. Famous and non-famous facial images were approximately 5.93 cm $\times$ 4.45 cm. Participants were tested at a viewing distance of 60 cm (faces thus subtended about 5.64 deg $\times$ 4.24 deg). During the test phase, intact famous and non-famous facial images were presented on a PC monitor with Superlab Pro software. The software recorded the participant's responses and the time between the onset of the stimulus, and the key-button press by the participant.

### 2.4 *Procedure*

During the prime phase of the experiment, participants viewed 15 faces in a random order on a Toshiba Satellite model 1400/2400 using Microsoft PowerPoint software. For the chimeric conditions, 10 faces were famous chimeras, and 5 were non-famous intact faces. For the half-face conditions, 10 faces were famous half-faces, and 5 were non-famous. In total, 20 famous chimeras and half-faces were used in order to counterbalance the faces that were primed and unprimed during the test phase. This ensured that any priming effects found were not due to a specific stimulus set. Non-famous faces were included during the prime phase in order to increase the possibility of false alarms (or participants incorrectly reporting the identity of a famous face). False-alarm rates were important for indexing recognition sensitivity ($d'$) (Miller 1996) for each prime condition.

[3] Examples of the dynamic chimeras and half-faces can be viewed at http://www.perceptionweb.com/misc/p5515/.

During the prime phase, participants were presented with dynamic and static chimeras and half-faces for 2 s per face, and were required to report the identity of any face that they thought resembled a famous person.[4] Presentation of facial stimuli during the prime phase was randomised. Where participants could not produce a name, appropriate semantic information (such as films that the person had been in, sports, or political positions that a person held) was accepted as a correct response.

After completing the prime phase, participants completed a 15 min unrelated face-recognition task, before completing the test phase of the experiment. The two experimental phases (prime and test phase) were presented to participants as unrelated experiments.

During the test phase, participants were presented randomly with static images of 40 intact faces (20 famous and 20 non-famous). 10 of the famous faces shared the identity of the top of the chimeras and half-faces that participants viewed during the prime phase. The remaining 10 were not viewed during the prime phase. The 20 non-famous faces shown had not been viewed during the prime phase. Each face was presented for 300 ms and participants were instructed to press the 'S' or 'L' key on a PC keyboard to indicate whether a face was famous or non-famous, respectively. Refer to figure 2 for examples of the stimuli used for the prime and test phases of the experiment.

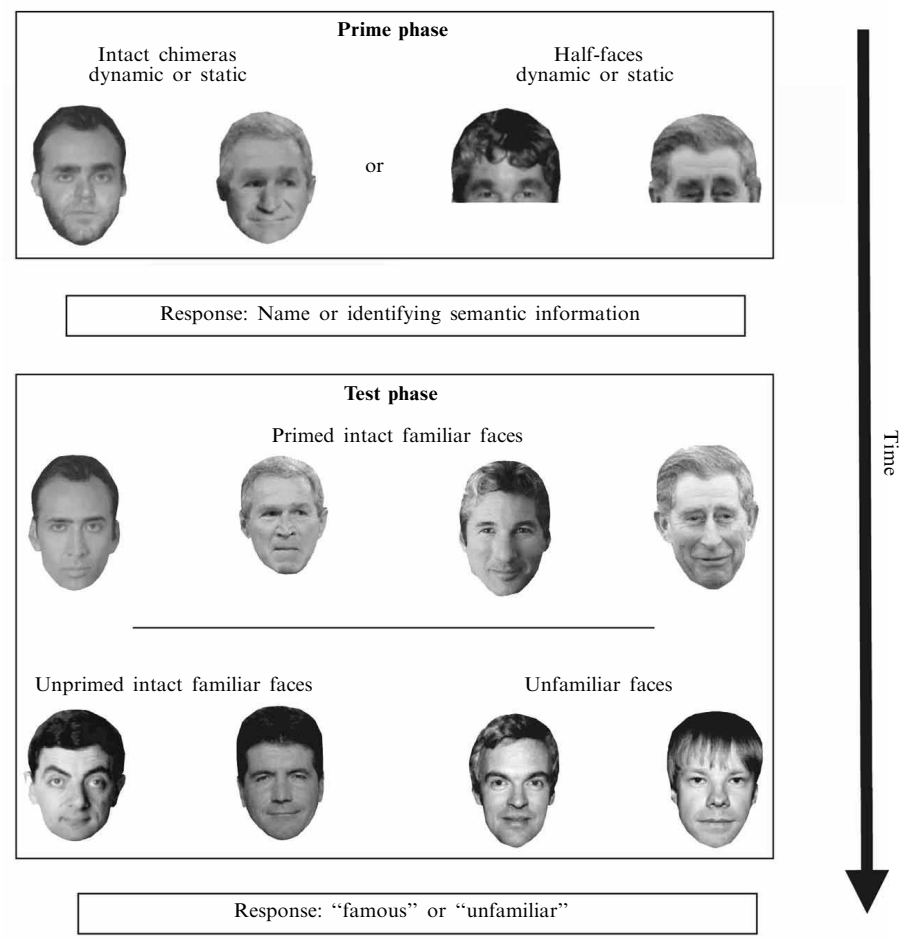


**Figure 2.** Outline of the prime and test phases of the experiment.

[4] Participants were not told to attend to the top half of the chimeras (as in Young et al 1987). This is because we were interested in examining the extent to which the familiarity of a chimera could influence face recognition and repetition priming when the face-recognition system processed the faces naturally.

At the end of the experiment, participants were presented with a slide showing all the famous faces that were used in the experiment, and were asked to try to recognise each face. If a participant could not recognise a famous face, it was discarded from all analyses in the experiment because it was assumed that the participant did not have a FRU for that particular individual.

## 3 Results

### 3.1 *Recognition of dynamic and static chimeras and half-faces*

Initial analyses were conducted to determine how accurately participants could recognise dynamic and static chimeras and half-faces. The proportion of faces in which participants gave a correct response to the identity of the top half (hits) was calculated for each condition, by dividing the proportion of faces that participants were able to recognise during the prime phase of the experiment by the proportion of faces that participants could identify from slides showing the famous faces used in the experiment.[5] The proportion of faces in which an incorrect name was given (false alarms) was also calculated. Proportions of hits and false alarms were used to calculate $d'$ (Miller 1996) for each of the four experimental conditions. These values are shown in figure 3. The proportions of faces correctly recognised (hit rates) in each experimental condition are also reported in the figure.

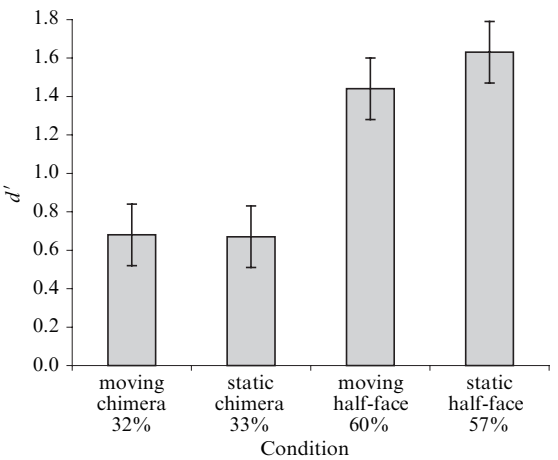


**Figure 3.** Mean $d'$ values for the recognition of dynamic and static chimeras and half-faces. Percentages represent the proportion of faces that were correctly identified in each condition. Error bars represent the standard error.

As seen in figure 3, it appeared to be the case that a larger proportion of half-faces was recognised compared to both types of chimera. There appears to be very little difference in the proportion of faces recognised in a dynamic compared to a static format in the chimeric and half-face conditions. This is consistent with the proportion of correctly recognised faces across the four prime conditions.

A 2 (stimulus type: chimera versus half-face) $\times$ 2 (presentation format: dynamic versus static) independent-samples ANOVA confirmed this impression, showing that, whilst the main effect of stimulus type was highly significant ($F_{1,58} = 28.14$, $p < 0.0001$, $\eta_p^2 = 0.33$), both the main effect of presentation format and the interaction between presentation format and stimulus type were not significant (both $F$s $< 1$).

[5] Very few participants (3/30) were able to recognise the identity of the bottom half of either the dynamic or static chimeras. Two participants in the moving chimeric condition were able to recognise the bottom half of the George Bush (top half) and Robin Williams (bottom half) chimera in spite of being unable to recognise its top half. One participant in the static chimeric condition was able to recognise the identity of the bottom half and top half of the Eminem (top half) and David Beckham (bottom half) chimera. This same participant also correctly recognised the bottom half and top half of the Richard Gere (top) and Keanu Reeves (bottom) chimera.

3.2 *Repetition priming for dynamic and static chimeras and half-faces*

Mean reaction times (RTs) for famous faces that were shown in a chimeric or half-face format during the prime phase were subtracted from mean RTs for famous faces not shown during the prime phase in order to yield mean priming rates for the four conditions.[6] The mean priming rates for the four conditions are shown in figure 4.

Figure 4 reveals that there was more priming when half-faces were presented during the prime phase than when chimeras were presented. There appears to be very little difference in priming when faces were presented statically compared to when they were presented dynamically in both conditions. Consistent with this, a 2 (stimulus type: chimera versus half-face) $\times$ 2 (presentation format: dynamic versus static) independent-samples ANOVA on the priming rates, revealed that both the main effect of presentation format and the interaction between presentation format and stimulus type were non-significant (both $F$s $< 1$). However, the main effect of stimulus type was significant ($F_{1,56} = 11.31$, $p < 0.01$, $\eta_p^2 = 0.17$), indicating that there was more priming for half-faces than for chimeras.

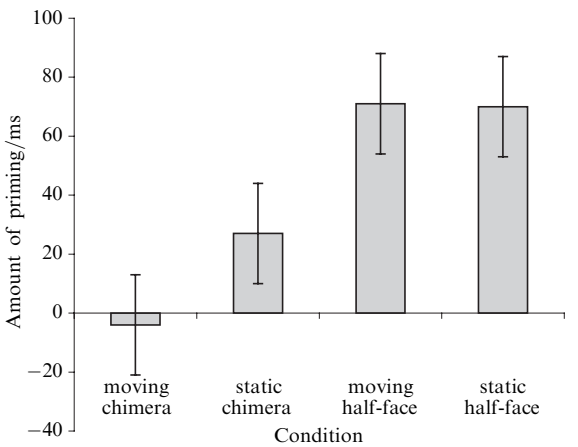


**Figure 4.** Mean rates of priming for dynamic and static chimeras and half-faces. Error bars represent the standard error.

Further analyses were conducted to determine whether priming for chimeras and half-faces was significantly different from 0. A one-sample $t$-test comparing the mean amount of priming in the chimeric conditions with the criterion value 0 revealed that, overall, priming for chimeras was not significantly different from 0 ($t_{29} = 1.02$, $p > 0.05$). However, priming was significantly different from 0 for half-faces ($t_{29} = 5.48$, $p < 0.0001$).

3.3 *Error rates for primed and unprimed faces*

Further analyses were conducted on the proportions of error responses generated during the test phase in which participants reported either a primed famous face (famous faces seen during the prime phase) or unprimed famous face (famous faces not seen during the prime phase) as unfamiliar. The differences between the mean error rates for primed and unprimed famous faces were very small (ranging from 3% to 5%) suggesting no significant differences in error rates across experimental conditions. Consistent with this, a 2 (prime type: primed versus unprimed) $\times$ 2 (stimulus type: chimera versus half-face) $\times$ 2 (presentation format: moving versus static) mixed ANOVA on error rates revealed no significant main effects or interactions (all $F$s $< 1.20$, all $p$s $> 0.05$). Therefore, the results are not compromised by a speed–accuracy trade-off.

[6] Only reaction times for famous faces that participants could recognise at the end of the experiment were included in this analysis. Participants were able to recognise the majority of faces used as primes and targets. Across conditions, on average, participants could recognise 9/10 prime and 9/10 target faces.

3.4 *Recognised and unrecognised chimeras and half-faces*

Subsequent analyses investigated test-phase performance in relation to whether or not recognition of stimuli occurred in the prime phase. The data were analysed by taking into account whether the stimuli were dynamic or static, and whether they were chimeras or half-faces. Priming for recognised primed faces was computed by subtracting mean RTs for recognised primed faces from mean RTs for unprimed faces. Priming for unrecognised primed faces was computed by subtracting mean RTs for unrecognised primed faces from mean RTs for unprimed faces.

Priming was very similar for recognised primed faces (ranging from 82 to 110 ms across the four conditions of the experiment). A 2 (stimulus type: chimera versus half-face) $\times$ 2 (presentation format: dynamic versus static) independent-samples ANOVA revealed non-significant main effects of stimulus type and presentation format and no significant interaction between them (all $F$s $< 1$). Priming for recognised faces was significantly different from 0 across the four conditions of the experiment (all $t$s $> 2.81$, all $p$s $< 0.01$).

Priming for unrecognised primed faces is shown in figure 5. As seen in the figure, there appears to be no priming for unrecognised primed faces across the four experimental conditions. Furthermore, the amount of priming is roughly equivalent across conditions (although priming appears to be negative for moving chimeras). A 2 (stimulus type: chimera versus half-face) $\times$ 2 (presentation format: dynamic versus static) independent-samples ANOVA confirmed this impression by showing a non-significant main effect of stimulus type, presentation format, and their interaction (all $F$s $< 1.47$; all $p$s $> 0.05$).

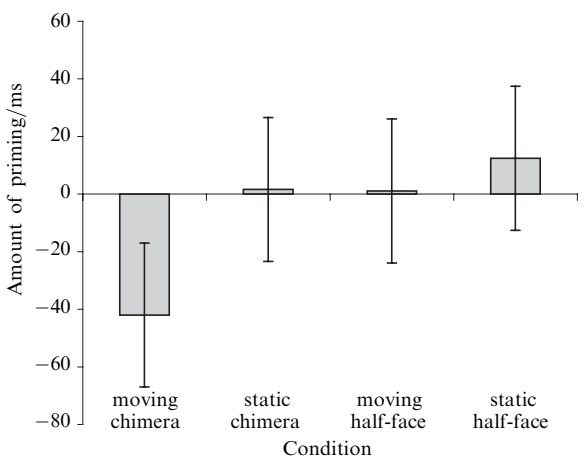


**Figure 5.** Mean rates of priming for unrecognised faces. Error bars represent the standard error.

## 4 Discussion

In this study, we evaluated the extent to which dynamic and static chimeras activate representations of their constituent faces, compared to half-faces. The main findings were that both types of chimera were difficult to recognise explicitly, and that repetition priming was severely impaired for chimeras compared to half-faces. Subsequent analyses were conducted to determine the amount of repetition priming caused by recognised and unrecognised chimeras and half-faces. When each type of facial stimulus was recognised, repetition priming was both significant and equivalent. In contrast, when each type of facial stimulus was unrecognised, no repetition priming occurred.

The low rates of recognition and repetition priming found for both dynamic and static chimeras extend Young et al's (1987) results by showing that the interference caused by aligning two halves of different famous faces not only increases the time required for explicit recognition of either half, but also severely reduces the activation

of the representation (or FRU) that corresponds to the top half of the chimera. This impaired activation of the upper donor face FRU does not allow the PIN of the upper donor face to be activated enough for repetition priming to occur (Burton et al 1990).

Another possible explanation for the deficits in recognition and repetition priming from chimeras is that the face-recognition system is activated by facial features on the top and bottom halves of facial chimeras. Activation resulting from one half of the features of a chimera may be offset by activation caused by the features of the other half of the chimera. This explanation is unlikely, given that Young et al (1987) did not find a chimeric face effect for inverted chimeric faces, which also retain featural information from two familiar facial identities.

Deficits in recognition and repetition priming for familiar chimeras are more likely to occur because the new configuration of features produced by a facial chimera constrains the way in which the features present in each half of the chimera are analysed. Consistent with this interpretation is a recent study which showed that altering the configurational properties of a face can change the perceived size of an individual facial feature (Collishaw et al 2005). Specifically, Collishaw et al showed that when the internal features of a face (eyes, nose, and mouth) were displaced up or down from their normal position, giving the impression of head tilt, judgments of the length of the nose were biased such that when the features were moved up in the face, the nose was perceived as being shorter more often than when the features were moved down. Taken together, it seems likely that the face-recognition system first computes a configurational facial analysis, before attention is given to the identity of individual facial features. The initial configurational analysis can influence the perceived size of the individual features (Collishaw et al 2005) and their utility for familiar-face recognition (present study).

The results also suggest that non-rigid facial motion does not influence the magnitude of the chimeric-face effect by either increasing holistic processing or by facilitating the perception of the upper facial features of a chimera. This result is consistent with research that suggests that non-rigid facial motion may benefit familiar-face processing only when the motion parameters match idiosyncratic facial movements that are stored in memory (Lander and Bruce 2000, 2004; Lander and Chuang 2005). Given that research has indicated that rigid facial motion (rigid translation of the entire head) may facilitate face learning by highlighting the structural properties of unfamiliar faces (Pike et al 1997), it may be the case that rigid motion (rather than the non-rigid movements used here) may influence the extent to which facial chimeras are processed holistically.

Another possibility raised by one of our reviewers is that perhaps the visual system treats a chimeric face as an unfamiliar face, despite the fact that it is comprised of two familiar faces. This interpretation is supported by the low rates of recognition seen in the prime phase of the experiment. If this were so, one would not necessarily expect non-rigid facial motion to improve recognition or produce repetition priming. Although facial motion has clearly been shown to aid recognition of famous faces, research on unfamiliar faces has produced somewhat more equivocal results, with some studies demonstrating a motion advantage (eg Lander and Bruce 2003; Pike et al 1997) but not others (eg Bruce et al 1999, 2001; Christie and Bruce 1998). The same reviewer also suggested that the benefit of motion found in previous research might rely on the presence of an intact familiar face.[7] Future research might explore whether artificially animating intact familiar faces leads to advantages in recognition or priming relative to viewing static familiar-face images. This research is important, given that there is very little research to support the utility of the REH (Roark et al 2003).

[7] We are very grateful to this anonymous reviewer for suggesting these two possibilities.

Analysis that was conducted to evaluate the amount of repetition priming for chimeras and half-faces revealed that significant priming occurred for facial chimeras only if their top half was explicitly recognised during the prime phase. This result is consistent with Brunas-Wagstaff et al (1992) and Johnston et al (1996), and indicates that repetition priming occurs only if a familiar face is explicitly recognised. On the basis of this result, a strong case can be made for the claim that repetition priming depends on above threshold activation of a FRU, and its corresponding PIN (Johnston et al 1996).

The experiment also revealed equivalent repetition priming for recognised chimeras and half-faces. This result was interesting given that, when a chimera was recognised in this experiment, participants tended to give a less certain response than when a half-face was recognised (eg "that face looks something like George Bush"). The successful parsing of the identity of the features of the top half of a chimera would account for the equivalent priming found for recognised chimeras and half-faces. Thus we suggest that the constituent halves of a chimera must be successfully parsed, and recognised, in order for a chimera to serve as sufficient input to activate representations of the top half of the face to which it belongs. A lack of a difference found in recognition and repetition priming for dynamic compared to static chimeras indicates that non-rigid motion does not help with the process of parsing the two halves of a chimera.

As repetition priming does not appear to occur unless a PIN and a FRU are activated above threshold, it may be the case that chimeras do activate FRUs, but the activation is not sufficient to lead to repetition priming. Studies conducted with brain-damaged individuals have used other methods that indicate that the face-recognition system may be partially activated by the presentation of familiar faces (de Haan et al 1987a, 1987b, 1992; Young et al 1988).

Of particular relevance here, de Haan et al (1987b) reported that a prospagnosic patient (PH) was faster at matching an image of an intact face to a different image limited to internal features of the same person when the two faces shown were familiar than when they were unfamiliar. PH was also faster at matching a familiar intact face to a face limited to internal features than he was at matching a familiar intact face to a face limited to external features.[8] However, PH performed at chance levels at a task requiring him to select from two facial images (a familiar face and an unfamiliar face) a face that was familiar to him. Researchers have suggested that PH's face-matching ability may have resulted from a damaged face-recognition system in which the activation of FRUs is sufficient enough to facilitate familiar-face matching, but insufficient to enable recognition (Burton et al 1991).

Thus, it may be useful to use a face-matching task to indicate whether facial chimeras partially activate representations of their constituent faces. Specifically, if participants can decide whether an intact familiar chimera matches an image of its internal features with more efficiency than when unfamiliar chimeras are used, it would seem likely that chimeras do cause some activation of FRUs. However, if decision times to match familiar and unfamiliar chimeras to their internal features are equivalent, it would seem that the interference caused by attaching two familiar-face halves gives the strong impression of a novel face which leads to null levels of activation of representations (or FRUs) of either of the donor familiar faces.

Recent prosopagnosic research supporting a matching advantage for dynamic faces comes from a study by Lander et al (2004). Lander et al measured the ability of a prosopagnosic (HJA) to decide whether two sequentially presented faces had the same identity. He was more accurate when they were presented moving (rigidly and non-rigidly) than when they were presented statically. Here it is possible that HJA could

[8] These results are consistent with those from familiar compared to unfamiliar face-matching studies conducted with normals (see Clutterbuck and Johnston 2005; Young et al 1985).

have been using similarities between the idiosyncratic facial motion patterns of the two faces, in order to decide whether the faces had the same identity (SIH). It is also possible that the rigid and non-rigid movements provided HJA better access to the structural properties of the faces (overall shape of face and facial features) (REH) than did the two static faces. Future research, using artificially animated familiar and unfamiliar chimeras and intact faces, will be needed to determine the extent to which rigid or non-rigid facial motion can facilitate face matching relative to static face images. This research will be important for determining both the validity of the REH as well as the extent to which the familiarity of the constituents of both dynamic and static chimeras can influence face matching.

**References**


Bailenson J N, Beall A C, Blascovich J, Rex C, 2004 "Examining virtual busts: Are photogrammetrically generated head models effective for person identification?" *Presence* **13** 416 – 427

Bauer R M, 1984 "Autonomic recognition of names and faces in prosopagnosia: A neuropsychological application of the Guilty Knowledge Test" *Neuropsychologia* **22** 457 – 469

Bourne V J, Hole G J, 2006 "Lateralized repetition priming for familiar faces: evidence for asymmetric interhemispheric cooperation" *Quarterly Journal of Experimental Psychology* **59** 1 – 17

Bruce V, Burton M, Carson D, Hanna E, Mason O, 1994 "Repetition priming of face recognition", in *Attention and Performance 15: Conscious and Nonconscious Information Processing* Eds M Moscovitch, C Umiltá (Cambridge, MA: MIT Press) pp 179 – 201

Bruce V, Henderson Z, Greenwood K, Hancock P J B, Burton A M, Miller P, 1999 "Verification of face identities from images captured on video" *Journal of Experimental Psychology: Applied* **5** 339 – 360

Bruce V, Henderson Z, Newman C, Burton A M, 2001 "Matching identities of familiar and unfamiliar faces caught on CCTV images" *Journal of Experimental Psychology: Applied* **7** 207 – 218

Bruce V, Valentine T, 1985 "Identity priming in the recognition of familiar faces" *British Journal of Psychology* **76** 373 – 383

Bruce V, Young A, 1986 "Understanding face recognition" *British Journal of Psychology* **77** 305 – 327

Bruce V, Young A, 1998 *In the Eye of the Beholder: The Science of Face Perception* (London: Oxford University Press)

Brunas-Wagstaff J, Young A W, Ellis A W, 1992 "Repetition priming follows spontaneous but not prompted recognition of familiar faces" *Quarterly Journal of Experimental Psychology: Human Experimental Psychology A* **44** 423 – 454

Burton A, Bruce V, Johnston R A, 1990 "Understanding face recognition with an interactive activation model" *British Journal of Psychology* **81** 361 – 380

Burton A, Young A W, Bruce V, Johnston R A, 1991 "Understanding covert recognition" *Cognition* **39** 129 – 166

Christie F, Bruce V, 1998 "The role of dynamic information in the recognition of unfamiliar faces" *Memory and Cognition* **26** 780 – 790

Clutterbuck R, Johnston R A, 2005 "Demonstrating how unfamiliar faces become familiar using a face matching task" *European Journal of Cognitive Psychology* **17** 97 – 116

Collishaw S M, Hole G J, 2000 "Featural and configurational processes in the recognition of faces of different familiarity" *Perception* **29** 893 – 909

Collishaw S M, Hole G J, Schwaninger A, 2005 "Configural processing and perceptions of head tilt" *Perception* **34** 163 – 168

Davies G, Ellis H, Shepherd J, 1977 "Cue saliency in faces as assessed by the 'Photofit' technique" *Perception* **6** 263 – 269

Haan E H de, Young A, Newcombe F, 1987a "Faces interfere with name classification in a prosopagnosic patient" *Cortex* **23** 309 – 316

Haan E H de, Young A W, Newcombe F, 1987b "Face recognition without awareness" *Cognitive Neuropsychology* **4** 385 – 415

Haan E H de, Young A W, Newcombe F, 1992 "Neuropsychological impairment of face recognition units" *Quarterly Journal of Experimental Psychology: Human Experimental Psychology A* **44** 141 – 175

Haig N D, 1986 "Exploring recognition with interchanged facial features" *Perception* **15** 235 – 247

Hill H, Johnston A, 2001 "Categorizing sex and identity from the biological motion of faces" *Current Biology* **11** 880 – 885

Hillger L A, Koenig O, 1991 "Separable mechanisms in face processing: Evidence from hemispheric specialization" *Journal of Cognitive Neuroscience* **3** 42 – 58

Johnston R A, Barry C, Williams C, 1996 "Incomplete faces don't show the whole picture: Repetition priming from jumbled faces" *Quarterly Journal of Experimental Psychology: Human Experimental Psychology A* **49** 596 – 615

Knappmeyer B, Thornton I M, Bülthoff H H, 2003 "The use of facial motion and facial form during the processing of identity" *Vision Research* **43** 1921 – 1936

Knight B, Johnston A, 1997 "The role of movement in face recognition" *Visual Cognition* **4** 265 – 273

Lander K, Bruce V, 2000 "Recognizing famous faces: Exploring the benefits of facial motion" *Ecological Psychology* **12** 259 – 272

Lander K, Bruce V, 2003 "The role of motion in learning new faces" *Visual Cognition* **10** 897 – 912

Lander K, Bruce V, 2004 "Repetition priming from moving faces" *Memory and Cognition* **32** 640 – 647

Lander K, Bruce V, Hill H, 2001 "Evaluating the effectiveness of pixelation and blurring on masking the identity of familiar faces" *Applied Cognitive Psychology* **15** 101 – 116

Lander K, Christie F, Bruce V, 1999 "The role of movement in the recognition of famous faces" *Memory and Cognition* **27** 974 – 985

Lander K, Chuang L, 2005 "Why are moving faces easier to recognize?" *Visual Cognition* **12** 429 – 442

Lander K, Humphreys G, Bruce V, 2004 "Exploring the role of motion in prosopagnosia: recognizing, learning and matching faces" *Neurocase* **10** 462 – 470

Maruyama K, Masame K, Endo M, 1988 "Sameness or not-sameness of the corresponding features and their summation effect in similarity judgment of faces" *Tohoku Psychologica Folia* **47** 74 – 84

Miller J, 1996 "The sampling distribution of $d'$" *Perception & Psychophysics* **58** 65 – 72

Morton J, 1969 "Interaction of information in word recognition" *Psychological Review* **76** 165 – 178

O'Toole A J, Roark D A, Abdi H, 2002 "Recognizing moving faces: A psychological and neural synthesis" *Trends in Cognitive Sciences* **6** 261 – 266

Pike G E, Kemp R I, Towell N A, Phillips K C, 1997 "Recognizing moving faces: The relative contribution of motion and perspective view information" *Visual Cognition* **4** 409 – 437

Renault B, Signoret J L, Debruille B, Breton F, 1989 "Brain potentials reveal covert facial recognition in prosopagnosia" *Neuropsychologia* **27** 905 – 912

Rhodes G, 1985 "Lateralized processes in face recognition" *British Journal of Psychology* **76** 249 – 271

Rhodes G, Brake S, Atkinson A P, 1993 "What's lost in inverted faces?" *Cognition* **47** 25 – 57

Roark D A, Barrett S E, Spence M J, Abdi H, O'Toole A J, 2003 "Psychological and neural perspectives on the role of motion in face recognition" *Behavioral and Cognitive Neuroscience Reviews* **2** 15 – 46

Rossion B, Dricot L, Devolder A, Bodart J M, Crommelinck M, Gelder B de, 2000 "Hemispheric asymmetries for whole-based and part-based face processing in the human fusiform gyrus" *Journal of Cognitive Neuroscience* **12** 793 – 802

Schiff W, Banka L, Bordes-Galdi G de, 1986 "Recognizing people in events via dynamic 'mug shots'" *American Journal of Psychology* **99** 219 – 231

Searcy J H, Bartlett J C, 1996 "Inversion and processing of component and spatial-relational information in faces" *Journal of Experimental Psychology: Human Perception and Performance* **22** 904 – 915

Shepherd J W, Ellis H D, Davies G M, 1982 *Identification Evidence: A Psychological Evaluation* (Aberdeen, UK: University of Aberdeen Press)

Stevenage S V, Lewis H G, 2002 "Understanding person acquisition using an interactive activation and competition network" *Visual Cognition* **9** 839 – 867

Tanaka J W, Farah M J, 1993 "Parts and wholes in face recognition" *Quarterly Journal of Experimental Psychology: Human Experimental Psychology A* **46** 225 – 245

Thornton I M, Kourtzi Z, 2002 "A matching advantage for dynamic human faces" *Perception* **31** 113 – 132

Young A W, 1994 "Conscious and nonconscious recognition of familiar faces", in *Attention and Performance 15: Conscious and Nonconscious Information Processing* Eds M Moscovitch, C Umiltá (Cambridge, MA: MIT Press) pp 153 – 178

Young A W, Hay D C, McWeeny K H, Flude B M, 1985 "Matching familiar and unfamiliar faces on internal and external features" *Perception* **14** 737 – 746

Young A W, Hellawell D, Haan E H de, 1988 "Cross-domain semantic priming in normal subjects and a prosopagnosic patient" *Quarterly Journal of Experimental Psychology: Human Experimental Psychology A* **40** 561 – 580

Young A W, Hellawell D, Hay D C, 1987 "Configurational information in face perception" *Perception* **16** 747 – 759

**Appendix**
**List of familiar faces used for dynamic and static chimeras and half-faces**

| **Top half of**: | **Bottom half of**: |
|---|---|
| 1. Rowan Atkinson | Anthony Hopkins |
| 2. Pierce Brosnan | Paul McCartney |
| 3. Christopher Reeve | Michael Douglas |
| 4. John Travolta | Mel Gibson |
| 5. Sylvester Stallone | Patrick Stewart |
| 6. Bill Clinton | Bill Murray |
| 7. Simon Cowell | Owen Wilson |
| 8. George Bush | Robin Williams |
| 9. Chevy Chase | Ben Affleck |
| 10. Harrison Ford | Jerry Seinfeld |
| 11. Justin Timberlake | Adam Sandler |
| 12. Tony Blair | Dustin Hoffman |
| 13. Prince Charles | Gordon Brown |
| 14. Eminem | David Beckham |
| 15. Jim Carrey | Leonardo DiCaprio |
| 16. Colin Firth | Robert De Nero |
| 17. Richard Gere | Keanu Reeves |
| 18. Nicolas Cage | Russell Crowe |
| 19. Arnold Schwarzenegger | Ben Stiller |
| 20. Sean Connery | Steve Martin |

Note: The top half of chimeras was used as primes for the half-face conditions. Intact versions of the top halves of the chimeras were used as target faces for the test phase.

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